MRS Sparse-FFT: Reducing Acquisition Time and Artifacts for In Vivo 2D Correlation Spectroscopy

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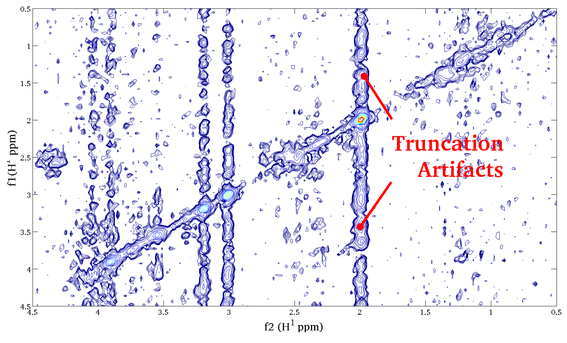
INTRODUCTION

2D COSY (2D Correlation Spectroscopy):

- Disentangling the spectral overlap of metabolites [1]
- Great potentials in detecting new molecular biomarkers of diseases [2]

Challenges with 2D COSY:

- Long acquisition time for the additional frequency dimension (f_1)
- Truncation artifacts along f_1 that obscure cross-diagonal peaks



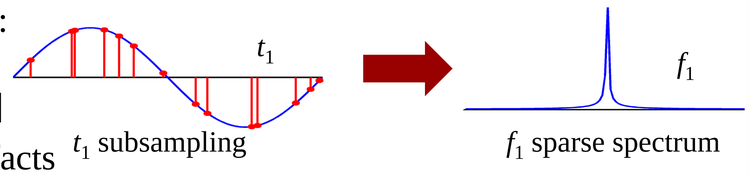
Approach:

- Adapting Sparse FFT algorithm [3,4] to exploit *sparsity* in the spectrum
- Suppression of truncation artifacts

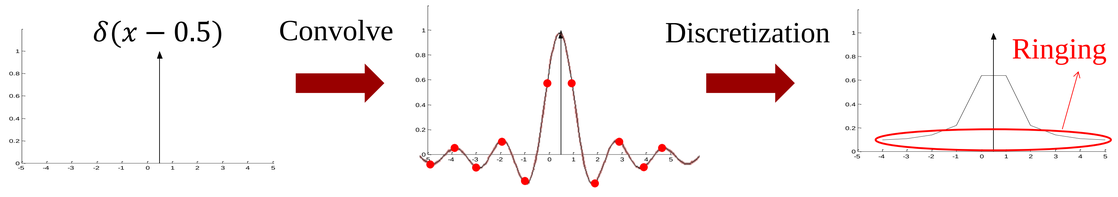
METHOD

MRS Sparse-FFT algorithm:

- Reducing acquisition time:
  - Subsampling t_1
  - Adapting Sparse FFT[3]



- Reducing Truncation Artifacts
  - Truncation in t_1 is convolution of sinc function in f_1
    - Multiplication of rect(t_1) ⇒ Convolution of sinc(f_1)
  - Cause of ringing: frequencies fall between two points of FFT grid



- Recover and subtract the ringing by finding the off-grid position

EXPERIMENT & RESULTS

Experimental method:

- Setup
  - Whole-body 3T MR scanner (Siemens, Erlangen)
  - COSY-LASER sequence [5] (TR=1.5s, TE=30ms)
  - Brain phantoms and 5 volunteers
- Baselines
  - FFT with the same N1 (number of t_1 samples)
  - Full FFT with larger N1
  - Compressive Sensing (CS)
  - QSine windowing and Linear prediction are performed for FFT and CS

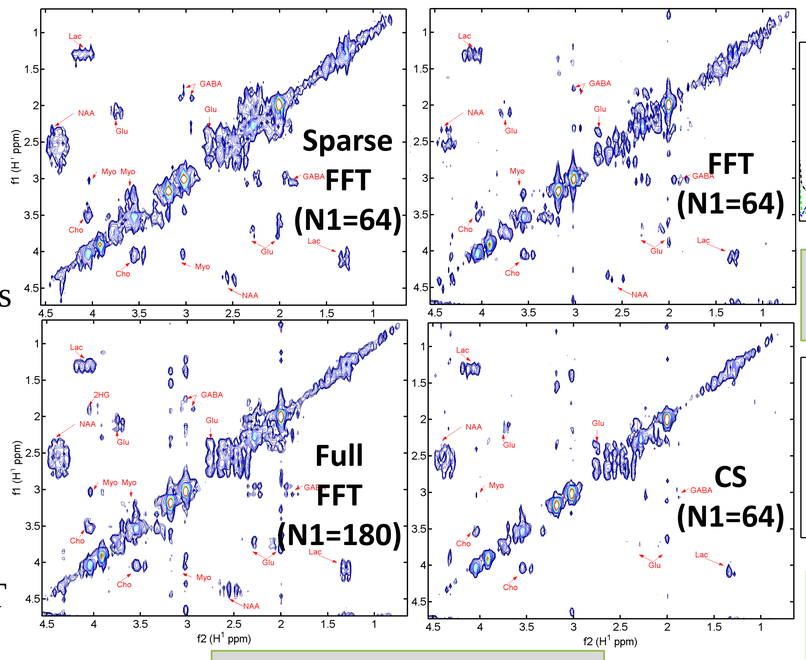


Fig. 1. Phantom Data Result

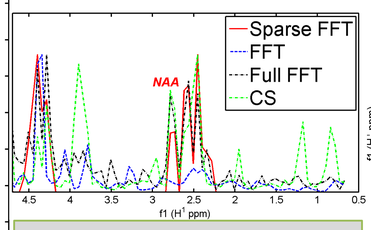


Fig. 3. Phantom Data (f_2=4.4 ppm)

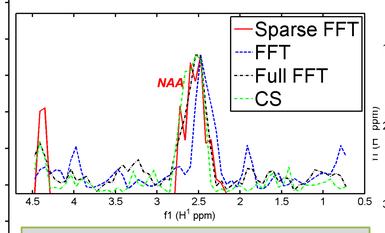


Fig. 4. In Vivo Data (f_2=4.4 ppm)

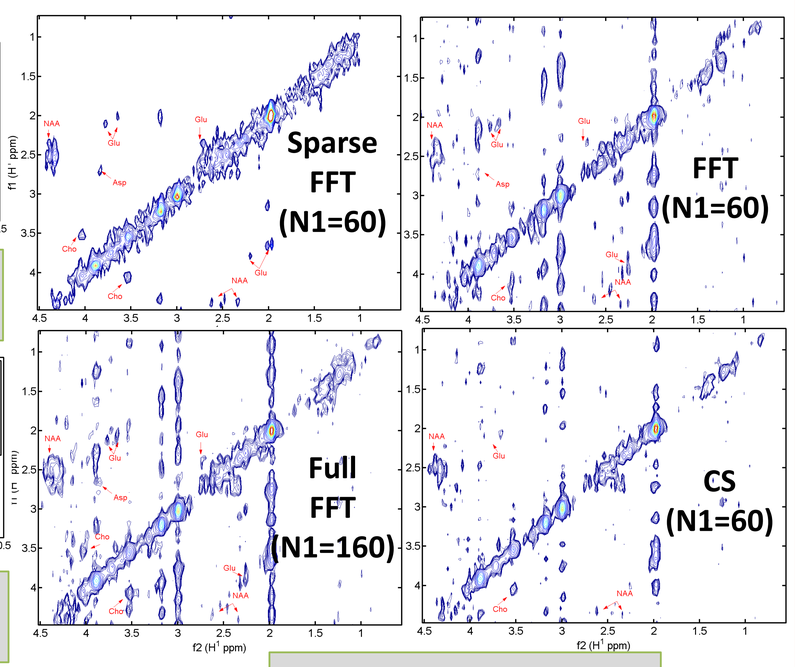


Fig. 4. In Vivo Data Result

Conclusion:

- The measurement time is reduced by a factor of 3-4 from full acquisitions
- We are superior to FFT and Compressive Sensing in terms of reducing f_1 artifacts and enhancing SNR
- MRS Sparse-FFT is less biased in finding the cross-peaks and my provide a more robust method in dealing with limitations of in vivo COSY
- Further validation and development is necessary for routine clinical applications.

	Phantom	In Vivo
Sparse FFT	0.17	0.15
Full FFT	0.23	0.24
FFT	0.15	0.15
CS	0.21	0.13

Table. 1. Line Width of NAA (ppm)

	Phantom	In Vivo
Sparse FFT	13.78	2.05
Full FFT	4.29	-11.7
FFT	0.84	-11.6
CS	-0.65	-13.3

Table. 2. Signal/Artifact Ratio (dB)

References: [1] M. A. Thomas et al., Magn. Reson. Med., vol. 46, pp. 58-67, 2001. [2] O. C. Andronesi, G. S. Kim, E. Gerstner, T. Batchelor, A. A. Tzika, V. R. Fantin, M. G. Vander Heiden, and A. G. Sorensen, Science Translational Medicine, vol. 4, p. 116ra4, 2012. [3] Hassanieh H, Indyk P., Katabi D., and Price E. STOC 2012. [4] Hassanieh H, Indyk P., Katabi D., and Price E. SODA 2012 [5] Andronesi OC et al, Magn.Reson Med. 2010;64(6):1542-56